THE INSTITUTION OF PRODUCTION ENGINEERS

JOURNAL

(December 1946, Vol. XXV, No. 12, Ed. B)

Contents:

PUBLISHED BY THE INSTITUTION
36, PORTMAN SQUARE, LONDON, W.1

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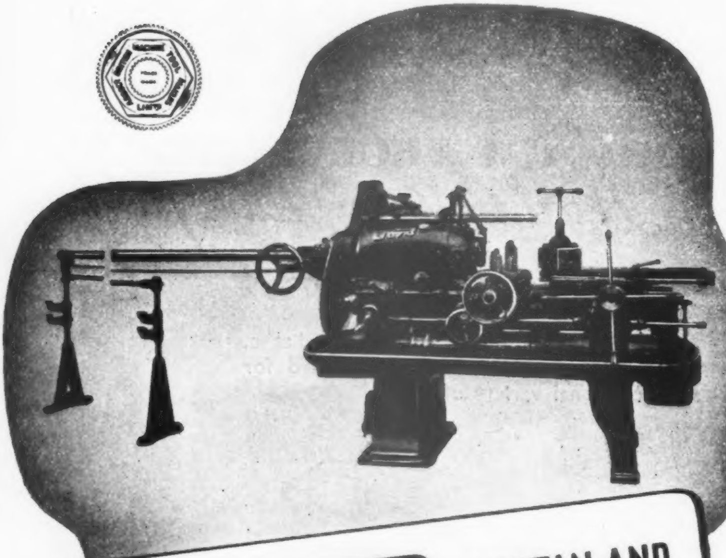

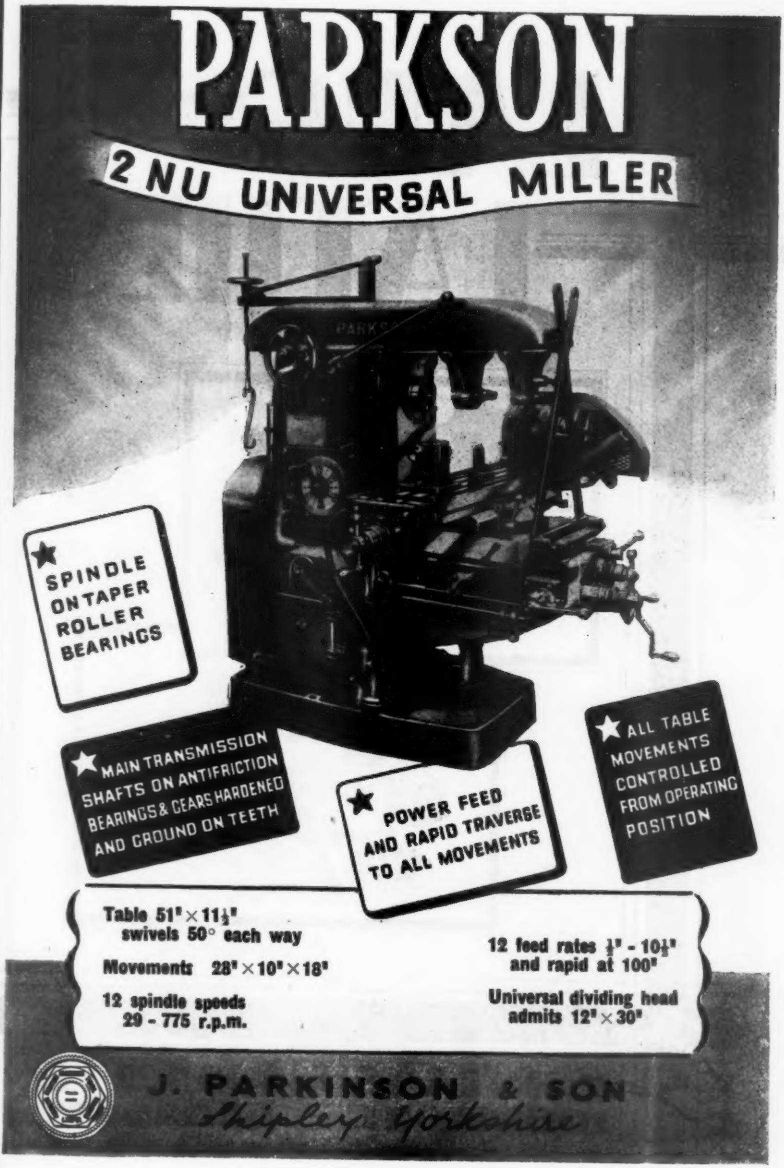
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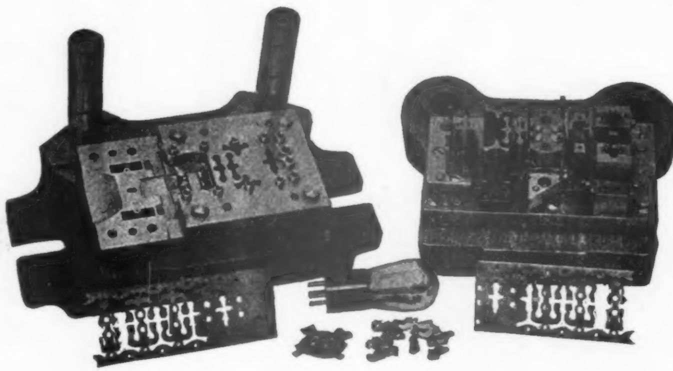

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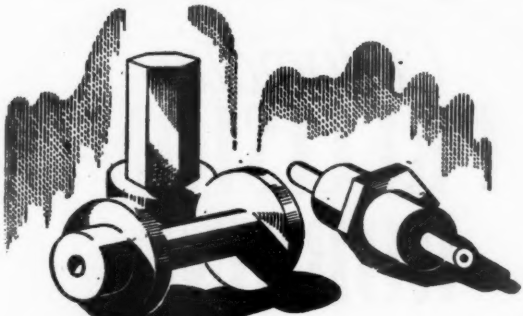

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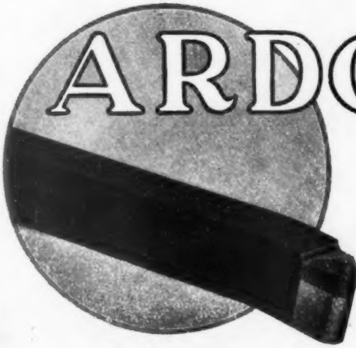

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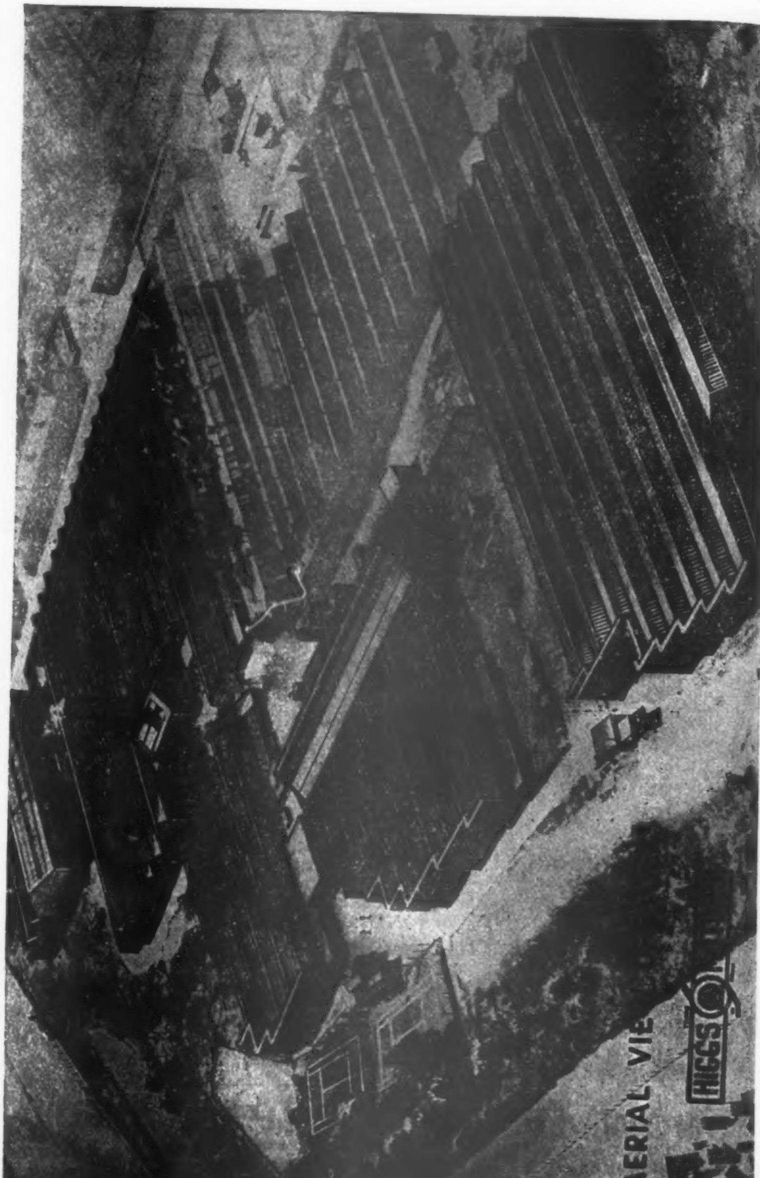
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INSTITUTION NOTES

December, 1946

December Meetings

2nd Coventry Graduate Section. A lecture will be given by Sir Donald Bailey, O.B.E., on "The Bailey Bridge," at the College Theatre, Coventry Technical College, Coventry, at 7 p.m.

2nd Yorkshire Section. A meeting has been arranged to take place at the Hotel Metropole, Leeds, at 7-00 p.m., at which papers on "Relationship between Research and Production Engineering" will be presented by Messrs. W. Armstrong, C. L. David, and R. J. Mitchell.

2nd Derby Sub-Section. A lecture will be given by Dr. Mullins on "X-Ray in Industry," at the Art School, Green Lane, Derby, at 6-45 p.m.

4th Nottingham Section. A lecture will be given by H. M. H. Fox, Esq., M.I.P.E., on "Outline of Modern Die Forging Practice," at the Victoria Station Hotel, Nottingham, at 7-00 p.m.

7th North-Eastern Section. A Social Evening has been arranged Details not yet available.

7th North-Eastern Graduate Section. A Works Visit has been arranged. Full details not yet available.

10th Birmingham Section. A lecture will be given by G. C. Stone, Esq., F.C.W.A., on "Costing for Engineering Production," at the Chamber of Commerce Building, New Street, Birmingham, at 7-00 p.m.

10th Birmingham Graduate Section. A lecture will be given by T. A. Edwards, Esq., H.M. Inspector of Factories, on "Some Requirements of the 1937 Factories Act," at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-15 p.m.

11th Luton and District Section. A lecture will be given by G. E. Windeler, Esq., on "Industrial Accidents," at the Central Library, Luton, at 7-00 p.m.

11th Preston Section. A lecture will be given by J. McFarlane, Esq., B.Sc., M.I.P.E., on "War-time Gauges and their Probable Influence on Post-war Gauging Methods," at Messrs. Clayton Goodfellow & Co., Ltd., Blackburn, at 7-15 p.m.

December Meetings—*Cont.*

12th Wolverhampton Section. A lecture will be given by Walter C. Puckey, Esq., M.I.P.E., F.I.I.A., on "The Gap Between Production Engineer and Manager," at the Civic Hall, Wolverhampton, at 7-00 p.m.

12th Leicester and District Section. A lecture will be given by R. K. Allan, Esq., A.M.I.Mech.E., M.I.P.E., on "Rolling Bearing Applications," at the Leicester College of Technology, Leicester, at 7-00 p.m.

12th Glasgow Section. There will be an Informal Discussion in the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m. Subjects for discussion will be tabled by Messrs. Buchanan and Wilson.

13th Eastern Counties Section. A lecture will be given by Dr. W. Wilson on "Electronics in Industry" at the Britannia Works, Colchester, at 7-15 p.m.

14th Western Section. The Eighth Annual Dinner will be held at the Grand Hotel, Broad Street, Bristol, 1, at 7-00 p.m.

14th Yorkshire Graduate Section. A lecture will be given by Lt.-Col. C. W. Mustill, M.B.E., A.M.I.Mech.E., M.I.P.E., on "Management," at the Great Northern Hotel, Leeds, at 2-30 p.m.

14th London Section. A visit has been arranged to Messrs. Standard Telephones & Cables, Ltd., Oakleigh Road, New Southgate, N.11.

16th Halifax Section. A lecture will be given by J. O. Cooke, Esq., of the British Standards Institution, on "Industrial Standardisation and the B.S.I.," at Whiteley's Cafe, Westgate, Huddersfield, at 7-00 p.m.

18th Sheffield Section. A lecture will be given by J. Rivers, Esq., M.I.P.E., on "Modern Trend in Heavy Machine Tool Design," at the Royal Victoria Hotel, Sheffield, at 6-30 p.m.

19th Luton and District Section. A visit has been arranged to Messrs. Vauxhall Motors, Ltd.

19th Glasgow Section. A lecture will be given by E. M. Trent, Esq., Met.Ph.D., and H. Eckersley, Esq., A.M.I.Mech.E., M.I.P.E., on "Manufacture and Application of Sintered Carbides," at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

December Meetings—*Cont.*

19th London Section. A lecture will be given by G. W. Nash, Esq., on "Production of Bevel Gears," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

20th Birmingham Graduate Section. A Christmas Dinner has been arranged by the Social Committee, to be held at the Imperial Hotel, Birmingham.

January Meetings

2nd London Section. A lecture will be given by G. Chelioti, Esq., on "The Structure of Management," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

6th Yorkshire Section. A lecture will be given by Peter Smith, Esq., on "Training Within Industry," at the Hotel Metropole, Leeds, at 7-00 p.m.

8th Luton and District Section. A lecture will be given by H. Eckersley, Esq., A.M.I.Mech.E., M.I.P.E., on "Manufacture and Application of Sintered Carbides," at the Central Library, Luton, at 7-00 p.m.

8th Nottingham Section. A lecture will be given by B. P. Cooper, Esq., M.I.Mech.E., on "Apprenticeship Training," at the Victoria Station Hotel, Nottingham, at 7-00 p.m.

10th North-Eastern Graduate Section. A lecture will be given by T. Burton, Esq., on "Elementary Principles of Cutting Tool Design," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

11th Yorkshire Graduate Section. A meeting has been arranged at the Great Northern Hotel, Bradford, at 2-30 p.m., when Short Papers will be given by Graduates and Students.

13th Halifax Section. A meeting has been arranged at the Technical College, Halifax, at 7-00 p.m., at which a sound film, "Steam," by Messrs. Babcock & Wilcox, Ltd., will be shown.

14th Birmingham Graduate Section. A lecture and film show on "The Manufacture of Optical Glass," will be given by Dr. R. E. Bastick, at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-15 p.m.

January Meetings—*Cont.*

15th Sheffield Section. A lecture will be given on " Research in Relation to Production Engineering " (lecturer's name not yet available), at the Royal Victoria Hotel, Sheffield, at 6-30 p.m.

16th Leicester and District Section. A lecture will be given on " Line Production of Footwear," by E. Eatough, Esq., at the Leicester College of Technology, Leicester, at 7-00 p.m.

16th Glasgow Section. A lecture will be given on " Measurement of Surface Finish," by C. Timms, Esq., M.Sc., A.M.I.Mech.E., at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

17th Western Section. A lecture will be given by G. H. Asbridge, Esq., on " Crushing Wheels for Form Grinding," at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

20th North-Eastern Section. A meeting has been arranged at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m., at which the following papers will be read : " Profile Machining," by N. J. Cooke, Esq., A.M.I.P.E., and " Preventive Maintenance of Machine Tools," by F. Ward, Esq., A.M.I.Mech.E.

20th Derby Sub-Section. A lecture will be given by W. Whitworth Taylor, Esq., on " Hydraulics as Applied to Machine Tools," at the Art School, Green Lane, Derby, at 6-45 p.m.

22nd Preston Section. A lecture will be given by V. W. Pilkington, Esq., M.B.E., M.Eng., M.I.Mech.E., M.I.A.E., on " The Training of Apprentices," at The Harris Institute, Avenham, Preston, at 7-15 p.m.

22nd Luton and District Section. A lecture will be given by H. E. Chastney, Esq., H.M. Chief Inspector of Factories, on " Factory Inspection," at the College of Technology, Manchester, at 7-15 p.m.

22nd Birmingham Graduate Section. A visit has been arranged to Messrs. Chance Bros. Ltd., Glassworks.

23rd Halifax Graduate Section. A lecture will be given by H. W. Fairbairn, Esq., on " Recent Developments in Die Castings," at the Technical College, Huddersfield, at 7-00 p.m.

January Meetings—*Cont.*

31st Eastern Counties Section. A lecture will be given by T. P. N. Burness, Esq., M.I.P.E., on " Production Methods as Applied to Machine Tools," in the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

31st Lincoln Sub-Section. A lecture will be given by E. R. Walter, Esq., Ph.D., M.Sc., on " Education and the Apprentice," at the Technical College, Lincoln, at 6-30 p.m.

Council Meeting

The next meeting of the Council will be held at 11-00 a.m. on 24th January, 1947, at the Institution of Civil Engineers, Great George Street, London, S.W.1.

GRADUATESHIP EXAMINATION, 1947

1 The Graduateship Examination of the Institution of Production Engineers will be held on Thursday and Friday, April 17th and 18th, 1947.

2 Forms of Application are obtainable either from the Head Office of the Institution or from the Honorary Secretary of any Section of the Institution, and must be despatched *so as to reach the Head Office not later than January 31st, 1947*, and must be accompanied by an entrance fee of ten shillings.

3 Candidates must be under 28 years of age.

4 Rules and Syllabus and past Examination Papers, price 3d, may be obtained from Head Office.

5 Full details of the Examination will be sent to every candidate.

Personal

Mr. J. E. Blackshaw, M.B.E., M.I.Mech.E., M.I.Loco.E., M.I.P.E., has recently been appointed Joint Managing Director of Messrs. G. D. Peters & Co., Ltd., Consolidated Brake & Engineering Co., Ltd., Slough, Bucks.

Mr. D. S. Clare, Inst.A.M.I.P.E., A.I.Mech.E., of the Hoffman Manufacturing Co., Ltd., has taken up an appointment as Technical Representative at the Head Office of Messrs. Associated Engineers Co., Ltd., Johannesburg.

Zinc Bulletin (New Series)

Members may be interested to know that the Z.D.A. Technical Bulletin has been revived under the title of " Zinc Bulletin."

This publication first appeared in 1942, but had to be abandoned

after the first issue owing to paper shortage. Since then, the Zinc Alloy Die Casters and the Zinc Pigment Development Association have been formed, in addition to the Zinc Development Association, and the re-named bulletin deals with the activities of all three organisations.

It is to be published quarterly, and will deal with the uses of zinc in its various forms, including technical articles and data sheets. Copies may be obtained free, on request from the Zinc Development Association, Lincoln House, Turl Street, Oxford.

Books Received

American Arc Welding Patents, edited by W. H. Simon. Ph.D. Published by Bailey Bros. & Swinfen, Ltd., London. Price £10 10s. net.

This work is an excellent contribution in a field which, as yet, has not been too well surveyed, and is an invaluable aid to the arc welding electrode and accessories industry. Its classification and indexing are particularly good.

Issue of Journal to New Members

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new members from the date they join the Institution.

Important

In order that the Journal may be despatched on time, it is **essential** that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

ANNUAL GENERAL MEETING

Friday, 4th October, 1946

The Twenty-fifth Annual General Meeting of the Institution was held at the Institution of Civil Engineers, Great George Street, London, S.W.1, on Friday, 4th October, 1946, at 2-00 p.m. Mr. N. Rowbotham, C.B.E., B.Sc., F.R.Ae.S., M.I.P.E., President, occupied the chair.

Notice Convening Meeting.

The DIRECTOR-GENERAL SECRETARY, Major C. B. Thorne, M.C., read the Notice convening the Meeting.

Message from the Immediate Past President.

The DIRECTOR-GENERAL SECRETARY read a telegram which had been received from the immediate Past President, Sir Robert McLean, regretting his inability to be present and wishing the new President a very happy and fruitful term of office.

The PRESIDENT said that when he accepted the invitation to become President of the Institution he received a very warm and encouraging letter from Sir Robert McLean. He was very sorry that Sir Robert was not able to be present.

Minutes.

The Minutes of the previous Annual General Meeting were read in abstract, confirmed and signed.

Election of Members of Council.

The DIRECTOR-GENERAL SECRETARY read the list of Officers and Members of Council for 1946/47.

Presidential Address.

The PRESIDENT, Mr. N. Rowbotham, C.B.E., then delivered his address :—

"Mr. Chairman, Ladies and Gentlemen,—On the occasion of this twenty-fifth anniversary of the Institution of Production Engineers, my first duty is to congratulate both the Institution and its members on having reached their present position so satisfactorily despite the grave difficulties of recent years. The founders of the Institution, far sighted though they were, could hardly have foreseen the terrific demands that were to be made in subsequent years on the production engineers of this country, nor the heavy responsibility that production engineering would have to bear in bringing the recent war to a successful conclusion.

" It has been said of other institutions that the first twelve years are the most difficult. Whether this statement is true or not, there are few who will deny that the first twenty years of an engineering institution's life are very difficult, especially if war intervenes. It is proper, therefore, that just tribute should be paid to the Founders and Members of the Institution who have so staunchly supported and cared for it over those years. Some of the most ardent are no longer with us, and the best memorial we can erect to their memory is a well balanced and substantial structure on the foundation they have laid.

" The present times are critical in many directions, and I would say that it behoves all who are concerned with the Institution's welfare to study carefully existing conditions and their effect upon organisations such as this. It is imperative that right decisions should be taken in the Institution's direction, its evolution planned in keeping with the national necessities of the future, and in addition unselfish enthusiasm in all its undertakings by its members throughout the country.

" A definition of Production Engineering perplexes many. Surely it may be said that Production Engineering is devising, and thereafter executing, economic means of manufacture to the requisite standards of quality and quantity. It is concerned with mining, textiles, hydraulics, automobiles, aircraft, and many other forms of engineering.

" Years ago a Production Engineer dealt with his subject in a very elementary way. His knowledge was limited—in many cases to his own shop floor—his tools and equipment equally limited, and probably his greatest asset was a full measure of skilled labour. Times have changed. It is essential now that the Production Engineer should understand a multitude of factors with which to operate :—metallic and non-metallic materials and their reaction to various processes, including turning, milling, grinding, honing, broaching, etc. ; experimental or small batch manufacture on the one hand, and on the other mass production ; shop layouts and working conditions ; progress systems and mechanical aids appropriate to the circumstances ; psychology of the supervisory staff and workpeople, and in fact a thousand and one items each of which must be properly studied and applied if the Production Engineer is to achieve the best results.

" Success in Production Engineering cannot be measured by the standards of recent years. During the war, production at any cost was essential, and even now with a seller's market prevailing costs are not of supreme importance. If we are to preserve a reliable economy in the years that lie ahead—and I venture to suggest that unless we do achieve a sound production economy the standard of living in this country will fall—it is essential that the Production

Engineer should be as skilled in his profession as any of his colleagues in theirs.

"This Institution has an important role to play in the life of the nation. I dare to say that it is no less important than that of kindred institutions, and in fact it may well prove to be even greater. No one will deny the excellence of invention and conception of engineering ideas emanating from British brains, but they must be co-ordinated with our highest production skill if we are to hold a pre-eminent place in world industry. From automobiles to aircraft, from beds to bulldozers, from coal to corundite, from dredgers to dynamos, and so throughout the alphabet—bright ideas will avail us little unless sound economic production technique is used in their manufacture. Each section of engineering has its own particular requirements and the Production Engineer must be capable of treating each according to the peculiar circumstances.

"Without belittling any of the efforts that have been made by Production Engineers in this country, I think there are lessons to be learned from overseas. It should be possible to obtain greater value in the finished product as sold to the customer than that which is generally available now. I would suggest that one of the reasons for this is to be found in many cases in the Production Engineer's opinion being sought too late by the designer, and in other cases his opinion discounted entirely. Great improvements are possible by encouraging the design engineer and the production engineer to work more intimately together, their joint efforts beginning with the original project. Time and other factors usually prevent anything but minor adjustments of the design at any later stage, and the final result is less perfect than it might otherwise have been.

"This Institution with its twenty-five years' background can do much to raise the level of the engineering industry of this Country and Commonwealth. Its standards of proficiency at the moment, less mathematical than some of the older institutions, must be under constant review. The subjects in which it is interested already cover a wide field and one which is continually extending. In education it must continue to play its part and its recommendations, I believe, will be welcomed by many colleges throughout the country. It should ensure being in the right position to give the best possible advice.

"In research, too, the Institution has already shown its keen interest and I suggest this interest should continue to increase. In this matter a word of warning may not be out of place—many other organisations are busying themselves with various branches of research and I believe that there is already considerable overlapping. I would recommend the Institution to take special care to avoid fostering research programmes which are already covered by work elsewhere, and to see that whatever research work it promotes is really objective.

"Finally, I am convinced that production engineering can look forward to a bright future full of new and interesting problems and covering an ever widening field of endeavour. It must be our earnest desire to see this Institution, after its twenty-five years' experience, taking a leading part in the sound progress of engineering as a whole and as may be most beneficial to our national life.

"This earnest desire can only be translated into practical achievement by a bold policy—not necessarily aggressive, but certainly progressive—on the part of your Council, with the support of all the members. I suggest that your Council, in reviewing the many problems with which it has to deal, must do so with the broadest possible outlook and certainly without hesitancy and indecision."

Mr. F. W. HALLIWELL proposed a vote of thanks to the President for his address. This was, he said, the Jubilee Year of the Institution, and marked an important milestone in its progress. For the first time for many years, the Institution had elected a President who was an ordinary member of long standing, who had been President of the Western Section in the 'thirties, and who had served as a Member of Council. That was an important event, and he looked forward to the time when the Institution would always elect its President from among its members, knowing that it had made the best possible choice. He felt that Mr. Rowbotham would put his shoulder to the wheel and work for the progress of the Institution. His address had been greatly appreciated, and contained much that was both pertinent and important.

Mr. T. FRASER, who seconded this proposal, said he had witnessed the growth of the Institution throughout its existence. Now, on its twenty-fifth anniversary, it had reached a stage of which its members might be justly proud. In Mr. Rowbotham, it had a President who would take a very live interest in its future progress.

The vote of thanks was carried with acclamation, and was briefly acknowledged by the President, who remarked that he had not been in the habit of associating himself with failures.

Annual Report and Accounts.

The CHAIRMAN OF COUNCIL, Dr. H. Schofield, C.B.E., presented the Accounts of the Institution for the year ending 30th June, 1946, and read the Annual Report of Council, which included the Annual Report of the Research Department.

THE INSTITUTION
OF PRODUCTION ENGINEERS

BALANCE SHEET

and

Income and Expenditure Account for the Year ended 30th June, 1946.

36 PORTMAN SQUARE LONDON W.1

THE INSTITUTION OF
BALANCE SHEET

LIABILITIES

	£	s.	d.	£	s.	d.
Sundry Creditors				1,738	9	5
Subscriptions Received in Advance				652	19	1
The Viscount Nuffield Gift	24,428	19	8			
The Lord Austin Prize Fund	100	0	0			
Hutchinson Memorial Fund	40	0	0			
Building and Development Fund	2,340	0	0			
				26,908	19	8
Leasehold Premises Sinking Fund	1,017	6	8			
Dilapidations Reserve Fund	500	0	0			
				1,517	6	8
Income and Expenditure Account:						
Balance at 1st July, 1945	12,020	8	5			
Add excess of Income over Expenditure for the year	1,053	7	4			
				13,073	15	9
Research Department:						
Sundry Creditors				511	12	0
Amount due to Head Office *per contra*				1,000	0	0
Balance of Income and Expenditure Account				454	2	11
				£45,857	5	6

Note.—Owing to the war, adjustments will be required at a future date in respect of certain of the assets included in the above account.

N. ROWBOTHAM, *President.*
HERBERT SCHOFIELD, *Chairman of Council and Finance Committee.*
C. B. THORNE, *Director General-Secretary.*

INCOME and EXPENDITURE ACCOUNT

EXPENDITURE

	£	s.	d.
To Salaries	7,608	9	7
,, Rent, Lighting, Heating and Cleaning	570	10	1
,, Local Section Expenses	1,019	10	6
,, Printing, Postage, Stationery and Telephone	2,309	1	6
,, Cost of Journal	4,176	11	5
,, Travelling and Expenses of Meetings other than Section Meetings	477	11	7
,, Professional Charges and Insurance	191	0	11
,, Donations and Grants	117	11	0
,, Repairs and Renewals...	204	5	0
,, Lord Austin Prize Fund	6	6	0
,, Miscellaneous	146	17	3
,, Transfer to Leasehold Premises Sinking Fund	127	3	4
,, Transfer to Dilapidations Reserve Fund	100	0	0
,, Amount written off Furniture, Fittings and Plant	174	12	8
,, Amount transferred to Research Department	6,463	10	9
,, Loss on Sale of Investments	6	9	7
	£23,699	11	2
,, Balance being excess of income over expenditure	1,053	7	4
	£24,752	18	6

PRODUCTION ENGINEERS

as at 30th June, 1946

ASSETS

	£ s. d.	£ s. d.
LEASEHOLD PREMISES at cost		3,481 0 0
(Depreciation is provided by a Sinking Fund)		
FURNITURE, FITTINGS AND PLANT at cost, *less* amounts written off:		
Balance at 1st July, 1945	619 17 5	
Additions during year	796 19 9	
	1,416 17 2	
Less Amount written off	174 12 8	
		1,242 4 6
FUND INVESTMENTS at cost: As Scheduled (Market value £28,980)		26,908 19 8
GENERAL INVESTMENTS at cost: As Scheduled (Market value £8,176) ...		7,772 10 0
SINKING FUND POLICIES: As Scheduled...		1,517 6 8
SUNDRY DEBTORS, DEPOSITS AND STOCKS		1,417 6 5
AMOUNT DUE FROM RESEARCH DEPARTMENT, *per contra*		1,000 0 0
CASH:		
At Bank	432 19 3	
At Post Office Savings Bank	1,108 15 0	
In Hand	17 16 0	
	1,559 10 3	
Less Overdraft on Current Account	1,007 6 11	
		552 3 4
RESEARCH DEPARTMENT:		
Laboratory Plant and Furniture at cost, *less* amounts written off ...		1,060 10 11
Stock of Publications, not valued		—
Sundry Debtors and Payments in Advance		218 17 3
Cash at Bank and in Hand		686 6 9
		£45,857 5 6

AUDITOR'S REPORT.—We have audited the above Balance Sheet dated 30th June, 1946, and we have obtained all the information and explanations we have required. The Australian Section Accounts are not included in the above Balance Sheet. Subject to the foregoing, in our opinion such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Institution's affairs according to the best of our information and the explanations given us, and as shown by the books of the Institution.

Aldwych House,
London, W.C.2.
23rd September, 1946.

GIBSON, APPLEBY & CO.,
Auditors,
Chartered Accountants.

for the year ended 30th June, 1946

INCOME

	£ s. d.	£ s. d.
By Subscriptions received—		
Current	13,867 2 1	
Arrears	485 10 0	
		14,352 12 1
,, Interest on Investments		1,078 4 8
,, Journal Receipts		4,416 12 10
,, Contributions received for Research	2,890 14 0	
,, Other Research Receipts	1,259 14 11	
		4,150 8 11
,, Transfer from Research for Management Expenses		500 0 0
,, War Damage Commission		255 0 0
		£24,752 18 6

RESEARCH

Balance Sheet as

LIABILITIES

	£ s. d.	£ s. d.
Sundry Creditors		511 12 0
Head Office		1,000 0 0
Income and Expenditure Account:		
Balance at 1st July, 1945	1,781 18 0	
Less Excess of Expenditure over Income for the year	1,327 15 1	
		454 2 11
		£1,965 14 11

N. ROWBOTHAM, *President of the Institution.*
MARK H. TAYLOR, *Chairman, Research Committee.*
C. B. THORNE, *Director General-Secretary of the Institution.*

RESEARCH

Income and Expenditure Account

EXPENDITURE

	£ s. d.	£ s. d.
To Salaries and Wages		4,955 10 11
„ Management Expenses		500 0 0
„ Rent, Light, Heating and Cleaning		83 17 11
„ Printing, Postages, Stationery and Telephone		107 4 10
„ Travelling and Expenses of Meetings		220 6 1
„ Professional Charges and Insurances		70 10 4
„ Cost of Technical Publications		533 9 7
„ Laboratory Materials		783 16 0
„ Repairs and Renewals to Plant and Equipment		92 8 4
„ Miscellaneous		22 7 8
„ Income Tax on Deposit Interest		2 15 0
„ Depreciation:		
Plant and Equipment	406 2 6	
Office Furniture	12 16 8	
		418 19 2
		£7,791 5 10

DEPARTMENT

at 30th June, 1946

ASSETS

	£	s.	d.	£	s.	d.
PLANT AND EQUIPMENT at cost, *less* amounts written off:						
Balance at 1st July, 1945	1,428	3	2			
Additions during year		—				
	1,428	3	2			
Less Depreciation	406	2	6			
				1,022	0	8
OFFICE FURNITURE at cost, *less* amounts written off:						
Balance at 1st July, 1945	44	16	6			
Additions during year	6	10	5			
	51	6	11			
Less Depreciation	12	16	8			
				38	10	3
STOCK OF PUBLICATIONS, not valued					—	
SUNDRY DEBTORS AND PAYMENTS IN ADVANCE				218	17	3
CASH:						
At Bank	662	7	4			
Deposit Account: Post Office	22	0	2			
Petty Cash in Hand	1	19	3			
				686	6	9
				£1,965	14	11

AUDITOR'S REPORT.—We have audited the above Balance Sheet of the Institution of Production Engineers Research Department dated the 30th June, 1946, and we have obtained all the information and explanations we have required. In our opinion such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Department's affairs according to the best of our information and the explanations given us and as shown by the books of the Department.

Aldwych House,
London, W.C.2.
23rd September, 1946.

GIBSON, APPLEBY & Co.,
Auditors,
Chartered Accountants.

DEPARTMENT

for the year ended 30th June, 1946

INCOME

	£	s.	d.	£	s.	d.
By Grant from Institution Funds				2,313	1	10
,, Transfer from the Institution of amounts received for Research:						
Contributions	2,890	14	0			
Bank and Post Office Interest		10	6			
Research Receipts	1,071	17	6			
Sale of Technical Publications	187	6	11			
				4,150	8	11
,, Balance being excess of Expenditure over Income				1,327	15	1
				£7,791	5	10

Schedule of Fund Investments.

	£	s.	d.	£	s.	d.
The Viscount Nuffield Gift:						
£7,124 19 10 3½% War Stock	7,428	19	8			
£8,389 9 6 3% National Defence Stock 1954-58	8,000	0	0			
£9,038 0 0 4% Canadian Pacific Railway Perpetual Consolidated Debenture Stock	9,000	0	0			
				24,428	19	8
The Lord Austin Prize Fund:						
£95 8 5 3½% War Stock				100	0	0
Hutchinson Memorial Fund:						
£37 17 3 3½% War Stock				40	0	0
Building and Development Fund:						
Loan to Treasury (free of interest)	1,050	0	0			
£1,000 0 0 3% Defence Bonds	1,000	0	0			
£274 12 0 3½% War Stock	290	0	0			
				2,340	0	0
Total as per Balance Sheet				£26,908	19	8

Schedule of General Investments (Unallocated):

	£	s.	d.
£644 15 2 Ayr County Council 3% Redeemable Stock, 1956 ...	650	0	0
£615 9 5 London County Consolidated 3% Stock, 1956-61 ...	620	0	0
£595 18 2 Plymouth Corporation 3% Redeemable Stock, 1956 ...	600	0	0
£148 3 11 3% War Stock, 1955-59	150	0	0
£382 13 8 3½% War Stock	400	0	0
£190 16 11 3½% War Stock	200	0	0
£95 8 5 3½% War Stock	100	0	0
£50 2 6 3½% War Stock	52	10	0
£5,000 0 0 3% Savings Bonds, 1965-75	5,000	0	0
Total as per Balance Sheet	£7,772	10	0

Schedule of Sinking Fund Policies.

	£	s.	d.
Leasehold Premises Sinking Fund:			
Norwich Union Life Insurance Society Policy—Premium Paid ...	1,017	6	8
Dilapidations Reserve Fund:			
General Accident Fire & Life Assurance Corporation, Ltd. Policy—Premiums Paid	500	0	0
	£1,517	6	8

ANNUAL REPORT 1945/46

During the year 1945/46 the Institution has made progress in relation to its stature, its membership and its stability, at a rate which eclipses that of any previous year in its history. In presenting its report, your Council makes the following observations.

Research.

During the past year, negotiations were concluded for the establishment of the Production Engineering Research Association of Great Britain, which was sponsored in its initial stages by the Institution of Production Engineers, the Gauge and Tool Makers' Association, the Machine Tool Trades Association and the National Federation of Engineers' Tool Manufacturers, together with His Majesty's Government, through the Department of Scientific and Industrial Research. The new organisation became a legal entity in June, 1946, and your Council at its meeting the same month, nominated the following gentlemen as the Institution's representatives on the Council of the new body :—

F. W. Halliwell (*Chairman*)
Dr. H. Schofield, C.B.E.
Mark H. Taylor
J. D. Scaife
J. E. Blackshaw, M.B.E.

It was further agreed that these gentlemen should form the new Research Committee of the Institution as from that date. In view of the foregoing, the Institution's Research Department established at Loughborough in 1939 was taken over by the new organisation on 1st July, 1946, and has now ceased to function as an integral part of this Institution.

Standards Committee.

The Standards Committee, which was in abeyance during the war, has now been reconstituted and has been meeting at regular intervals, first under the chairmanship of Mr. H. A. Hartley, and now under that of Mr. J. E. Baty.

Unification of Screw Threads.

During the year, various Sections of the Institution throughout the British Commonwealth held discussions on the vitally important subject of Unification of Screw Threads between Great Britain, Canada and the United States of America. A consolidated report on their findings was drawn up by the Standards Committee, who found that the views expressed by the Institution were very much in agreement with the recommendations made at the Conference on Unification of Engineering Standards held at Ottawa in October

1945. In consequence, on 28th June, your Council passed a resolution pledging the Institution's wholehearted support to His Majesty's Government and the British Standards Institution in giving effect to the recommendations of the Ottawa Conference. This arose out of the above-mentioned report embodying the views of Sections as set out in detail in the Council Papers of June 1946.

Association of Technical Institutions.

The Association of Technical Institutions invited a strong delegation from the Institution of Production Engineers to attend their Annual Meeting held in London on 22nd February, 1946. The address delivered by our then President, Sir Robert McLean, on "The Training of the Production Engineer," was extremely well received and was followed by a full discussion between the Principals of the Technical Colleges and the members of the Institution's delegation. This contact with the Technical Colleges was extremely valuable, and it is hoped that closer liaison between Sections and the Technical Colleges will lead to a wider interest in Production Engineering courses generally. Copies of the Institution's Journal are now being sent to 165 Technical Colleges throughout the U.K.

College of Aeronautics.

His Majesty's Government invited the Institution to send a delegation to meet the governing body of the recently established College of Aeronautics, together with representatives of the Ministry of Education, with a view to discussing the advisability of including Production Engineering courses in the curriculum of the new College. A final decision concerning this matter has not yet been made.

Calcutta Section.

The newly formed Calcutta Section of the Institution held its inaugural meeting on 28th February, 1946. In view of future industrial developments in India, this Section should mark the beginning of a large field for Production Engineers in that country.

South African Association of Production Engineers.

Negotiations have been entered into with the South African Association of Production Engineers with a view to bringing about some form of amalgamation between our two bodies. This Association at present has a membership of 179 and operates through two branches, one in Johannesburg and the other in Cape Town. Latest statistics indicate that Engineering Industries in the Union of South Africa are steadily increasing. Therefore, such an amalgamation, if it can be brought into being, should mutually benefit both bodies.

Formation of New Section in U.K.

The formation of a Halifax Graduate Section was approved by Council in December, 1945. A number of meetings have already been held by this Section, its inaugural meeting being held on 28th September, 1946.

Hazleton Memorial Library.

An appeal was launched for the formation of a Library to commemorate the late Mr. Richard Hazleton, former General Secretary of the Institution. It is hoped that the response to this appeal will be such that the Institution will be able to establish a first-class reference library of which it can be justly proud.

Increase in Membership.

The membership of the Institution has increased by 1,102 members during the financial year. The total membership as at 30th June, 1946, was 6,321. This figure is made up as follows :—

Honorary Members	3
Members	1,056
Associate Members	1,880
Associates	130
Intermediate Associate Members ...	1,233
Graduates	835
Students	737
Affiliated Firms	194
Affiliate Representatives	253
	6,321

Finance.

The accounts for the year ended 30th June, 1946, show an excess of income over expenditure of £1,053 7s. 4d., as compared with the excess of income over expenditure of £3,474 1s. 6d. on 30th June, 1945. It should be borne in mind, when comparing these figures, that the drastic reorganisation which has taken place during the past year has necessarily involved some non-recurring expenditure which was accurately forecast in the budget. The benefit of this reorganisation, coupled with the increased membership during the year, will no doubt show itself in the Accounts for the year ending 30th June, 1947.

Education.

The Lord Austin Prize for 1945/46 was awarded to Mr. Ian McLeod, A.M.I.P.E., for his Essay "The Place of Plastics in Jig and Fixture Design." The prize, consisting of books, together

with a certificate, was presented to Mr. Ian McLeod by the President-Elect, Mr. N. Rowbotham, C.B.E., at the Members' Luncheon, held at the Dorchester Hotel on 17th May, 1946.

Council has approved the revival of the Hutchinson Memorial Prize, to be awarded for the best paper by a Graduate. This will take effect during the year 1946/47.

Graduateship Examination.

Of the 64 candidates who sat for the Graduateship Examination this year, 21 passed and 43 failed. It will be noted that the number of candidates taking this examination is lamentably small. This is a matter of immediate importance.

Technical and Publications.

(*a*) *Journal.* The main concern of the Technical and Publications Committee is the production of the Journal, and in this respect vigorous and successful efforts have been made to obtain a steady supply of up-to-date papers for the Committee's consideration. It is hoped in the near future to publish papers in the Journal in advance of their presentation to Sections.

(*b*) *Liaison with Technical Press.* The Committee believes most strongly in the importance to the Institution of sound liaison with the Technical Press, and to this end has appointed a Sub-Committee to establish a satisfactory procedure.

(*c*) *Technical Enquiries.* The Committee continues to receive a steady flow of technical enquiries, and has in the majority of cases been able to supply satisfactory information.

Honours.

The following honours have been conferred upon members by H.M. the King :—

Norman V. Kipping ... Knighthood.

Dr. H. Schofield ...	C.B.E.	T. Fraser	C.B.E.
J. E. Blackshaw ...	M.B.E.	R. W. Poyser ...	M.B.E.
D. F. Horne ...	M.B.E.	W. Bentley ...	M.B.E.
G. L. Norman ...	O.B.E.	F. C. Robinson ...	M.B.E.

Obituary.

We deeply regret to record the death of Mr. J. A. Boyes, M.I.P.E., Mr. Boyes was an active member of the Institution, and was President of the Coventry Section 1937/38. At the time of his death, he was a member of the Coventry Section Committee, and also of the Education Committee. We also regret to record the death of

Mr. John Arthur, M.I.P.E., Secretary of the Cornish Section from its inauguration in 1938 until September 1945. Mr. Arthur did invaluable work in the development of this Section.

We also announce with regret the death of the following members: W. E. Billington, Grad.I.P.E., Bernard E. Curran, A.M.I.P.E., E. A. C. Dell, A.M.I.P.E., J. R. Gimson, M.I.P.E., G. L. Litchfield, A.M.I.P.E., E. L. Lovejoy, A.M.I.P.E., J. Low, A.M.I.P.E., E. A. Molesworth, M.I.P.E., C. H. Rathbone, Grad.I.P.E., J. S. Reed, M.I.P.E., A. J. Shelley, M.I.P.E., H. Thompson, A.I.P.E., H. G. Williams, M.I.P.E., D. Willson, M.I.P.E., and W. A. Jaffrey, A.M.I.P.E. (Melbourne).

The Report and Accounts were adopted.

Election of Auditors.

On the motion of Mr. F. W. Halliwell, seconded by Mr. R. Kirchner, Messrs. Gibson, Appleby & Co., Chartered Accountants, were re-elected Auditors to the Institution for the year 1946/47.

Election of Solicitors.

On the motion of Mr. J. E. Hill, seconded by Mr. A. L. Stuchbery, Messrs. Syrett & Sons, were re-elected Solicitors to the Institution for the year 1946/47.

Votes of Thanks.

The President moved a vote of thanks to the immediate Past President, Sir Robert McLean; to the retiring Chairman of Council, Mr. J. E. Blackshaw; to the Section Hon. Secretaries; to the Director-General Secretary; and to the Headquarters' staff.

Mr. J. E. Hill, who seconded, asked that the name of Mr. George Hales should be included, in view of his retirement and of all the years of work that he had done for the Institution.

The vote of thanks, with this addition, was carried with acclamation. The Annual General Meeting was then terminated.

ADDRESS BY THE CHAIRMAN OF COUNCIL UPON TAKING UP OFFICE.

The CHAIRMAN, Dr. H. Schofield, C.B.E., in expressing his great appreciation of the honour paid him in asking him to take the Chair, said there were many who might regard him as an academic person, but in addition to being a pedagogue, he was at the head of a well-known industrial undertaking which was very much concerned with the technique of production engineering on a large scale and which, had it not tackled the many difficulties associated with production would not occupy the position in the world that it did to-day.

From the early days of the Institution he had enjoyed the friendship of the late Richard Hazleton, of whom it could be said "he builded better than he knew"; the Institution would ever honour his memory.

Personally, he was very much concerned with the development of the Institution and the place which it would hold in the national life. As a Corporate Member of the Institutions of Civil, Mechanical and Electrical Engineers, he could say that the Institution of Production Engineers had a fairly long way to go, but it would do it. The result of the Graduate examinations had been announced at the Annual General Meeting, and progress was being made with the Higher National Certificate. From the report it was obvious that a great deal had to be done regarding its examinations if the Institution was to command the respect to which it was entitled.

As soon as it was financially possible, the Institution should have an education officer, whose primary duty it would be to attend to that side of its activities, who could address with authority an audience on production engineering, and who would be able to meet on the right plane the heads of colleges who were concerned with the academic training of the future Corporate Members of the Institution. He would like to see that achieved before his term of office expired, and in any case he regarded it as a foundation stone of future policy. Judging by what could be seen of the future, it should not be long before this was financially possible.

Whilst paying tribute to the work of the Technical and Publications Committee and to the excellence of the *Journal*, he felt that in the past they had confined themselves too exclusively to pure technology. Production engineering had a strong humanistic side, and he would like to see articles in the *Journal* covering a wider field

He would like to pay tribute to one who had in recent years done a good deal to help the Institution forward, his good friend Dr. Schlesinger. He was owed a great deal for his pioneering work, in

starting the Research Department from very small beginnings with a minimum of equipment and staff. The more one knew him the more one respected his encyclopaedic knowledge, and the Institution should place on record how much was due to him for that work which he carried out with the enthusiastic support of Richard Hazleton. Without their joint efforts the position with regard to the Production Engineering Research Association of Great Britain would not be what it was to-day. It must always be to the credit of the Institution that it made that great development possible.

He would also pay tribute to the work done during the past year by the Director-General Secretary. Major Thorne had vision, enthusiasm and ability, three characteristics seldom to be found in one individual. He wanted Major Thorne to feel that the Council were behind him in his ideas for the development of the Institution, and that he could go forward with their encouragement and support. "With his and your support," the Chairman said in conclusion, "I hope that this year will be a very profitable one for the Institution, and that we shall take great strides forward in establishing a degree of national prestige more in keeping with the important part which Production Engineering plays in the life of the nation."

APPLICATIONS FOR MEMBERSHIP AND TRANSFER RATIFIED AT MEETING OF COUNCIL
October 4th, 1946

(*a*) **Election of Members by Council.** The following applications for Membership were considered and dealt with by Council :—

As Associate Members : W. M. Carreck, E. A. Gordon, A. C. Wilson.

As Intermediate Associate Members : A. L. Preston, J. M. Rattray.

(*b*) **Election of Members confirmed by Council.**

As Members : V. W. Burrough, J. J. Gracie, B. C. Harrison, T. J. Luby, G. S. Manners, H. J. Millard, L. T. Morton, A. J. Perkins, J. R. Pheazey, S. E. Willett, G. W. Wright.

As Associate Members : E. Alexander, R. H. Baines, J. H. Barnard, J. W. Carpenter, J. A. Dancker, C. W. Done, C. H. H. Downing, A. H. Evans, S. R. Evans, G. O. Everett, D. H. Goodreid, W. A. Harrison, H. G. Harwood, J. J. Haythornthwaite, W. A. Hearsum, C. G. Hefford, H. R. Hicks, H. C. Horner, J. A. Humphries, E. E. Ingleton, T. A. Jinks, H. Spencer Jones, K. B. P. Lee, J. H. Lower, A. J. Lund, E. Marsland, A. L. Martin, R. G. P. Mayo, J. R. Nicholls, J. Pickles, J. L. Ramsey, A. M. Redman, W. G. Rodgers, R. E. Scott, J. D. Shackleton, Jang Bir Singh, C. L. Sykes, G. W. Toman, W. Udall, G. Whyatt.

As Associates : J. A. Bullock, F. S. Grace, C. G. Roper.

As Intermediate Associate Members : N. H. Ashworth, P. A. Barber, F. W. H. Barker, W. R. Beale, P. S. Boutell, P. S. G. Cadman, R. Clark, F. A. Claxton, N. J. Cowell, F. Dolby, N. A. Dudley, E. N. Dyson, H. L. Fardon, E. Gascoigne, A. Godfrey, F. Hampson, T. Hardie, R. G. Harvey, C. E. Hill, V. H. Hoyland, S. H. Inglis, A. T. Jones, W. Kerr, F. T. Kosh, W. J. Lewis, A. E. J. Nicholls, G. W. Powles, H. S. Pratt, R. E. Raaschou, W. A. Sargent, B. W. Smith, E. Smith, V. W. Talbot, R. T. Teasdale, A. E. Thomas, C. Walker, S. A. Warwick, R. Wildey, E. R. O. Woodgate, J. H. Wright.

As Graduates : R. F. C. Acford, D. Allott, R. N. Allen, C. Allsop, W. Banes, F. Bartram, W. H. Bone, J. Kemsey Bourne, T. E. Burnup, I. H. Calder, R. R. C. Came, W. P. Collier, R. Dayal, G. Fox, J. D. Haigh, E. Hall, R. F. Holmes, R. D. Homer, K. Johnson, M. Kenyon, W. E. Langley, G. Leech, F. J. Maloney, R. Moggridge, P. Newby, E. R. Nicholls, A. E. V. Page, T. H. Perrin, P. R. Shackleford, E. H. Shaw, E. Ward, A. J. Warner, E. N. White.

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HIGH FREQUENCY INDUCTION HEATING

By E. May, B.Sc., and T. G. Tanner, B.Sc.

Presented to Yorkshire Section, 7th October, 1946.

Introduction.

The idea of high frequency heating is not new—the discovery of it dates back to the last century—but the realisation that high frequency energy could be applied to induction heating on an industrial scale did not come about until towards the close of the first world war.

The early years in the industrial development of high frequency heating saw the production of small spark gap oscillator furnaces for the laboratory and for small scale production melts.

The next stage of development can be seen in the period 1925 to 1933, during which time high frequency energy, obtained by means of motor alternators, was applied very extensively to large scale melting operations.

The years since 1933 have seen the extension of the industrial use of high frequency energy to the heating of all types of metals, as distinct from the melting of them. The development of industrial equipment for heating metals by high frequency induction has given the metallurgist and the production engineer an entirely new tool with revolutionary possibilities. By such means, virtually any amount of heat can be applied to any portion of a metal object, and at a higher rate than by any other commercial process. Nevertheless, high frequency heating has limitations which must be clearly recognised, no less than its remarkable advantages. To mistake its proper sphere may be just as bad as to ignore its true possibilities.*

It is proposed to consider briefly the theory underlying this system of heating, then to describe the type of plant involved, but the majority of this paper will be devoted to the methods of applying induction heating and to a review of actual applications.

Theory.

Induction heating—that is, the heating of electrically conducting materials by inducing eddy-currents in them—makes use of two well-known effects associated with alternating-current circuits. The first is mutual induction ; the power transformer and the induction motor are familiar machines which depend upon this same effect, namely, the induction of an alternating current in an electric circuit, which is in favourable proximity to another ("primary") circuit

*An account of the history of induction heating will be found in *The Iron Age*, 22nd March, 1945. (See Bibliography 1.)

supplied with alternating-current energy. The second effect is the peculiar distribution of an alternating current in its conductor. An unvarying "direct" current is distributed uniformly throughout the cross-section of a conductor (if we ignore "streamline effects" due to sudden changes of section), in conformity with the law of minimum dissipated energy which governs such a flow; *i.e.*, the current distribution is that which results in a minimum rate of heat generation. An alternating current, however, tends towards a distribution which results in a minimum associated magnetic-field energy (2), even though this may require an enormous increase in dissipated energy and hence in heat generation. "Skin" and "Proximity" effects are examples of this minimum-magnetic-energy a.c. distribution; they are pronounced even at 50 c.p.s. in

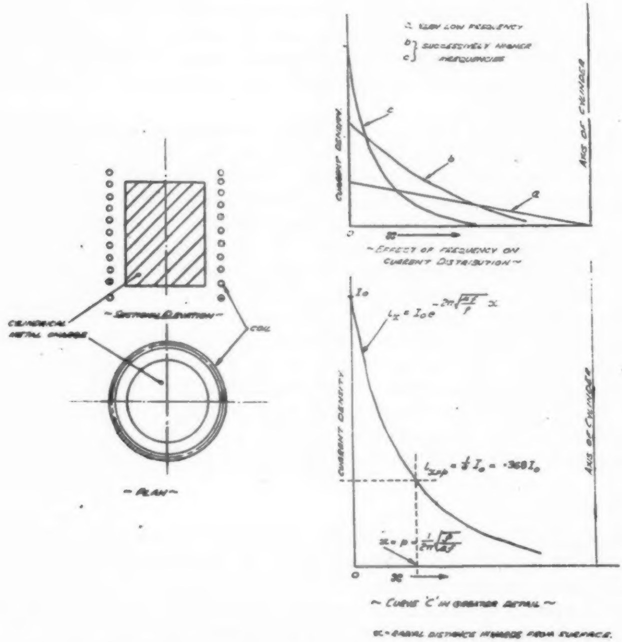

FIG. 1. Distribution of induced current in a solid metal cylinder. For surface-hardening, the frequency should be high enough to make *p* equal to or less than the hardened layer depth required. Efficient through-heating requires *p* not greater than ¼ of cylinder diameter.

circuits of large dimensions, but they are exploited, in the induction-heating of metal parts of small dimensions, by increasing the supply frequency to some thousands or hundreds of thousands of cycles per second.

Consider now a solid metal cylinder, the work piece which is to be heated, surrounded by a primary coil, illustrated in Fig. 1. The alternating current in the coil induces a counter-current in the cylinder, and this current is distributed through the cross-section as shown ; if the supply frequency is sufficiently high, or the cylinder diameter sufficiently large for the current distribution to be represented by a curve such as (C) in the figure, then the effective "penetration depth" of the current may be taken as

$$p = \frac{1}{2\pi} \sqrt{\frac{\rho}{\mu f}} \text{ cms.}$$

Where ρ = electrical resistivity of cylinder material, in e.m. units, *i.e.*, ohm-cms $\times 10^9$

μ = magnetic permeability of cylinder

f = coil supply frequency, cycles per second.

The majority of applications to steel heating require final temperatures in excess of the magnetic change-point (around 720°C.), when $\mu = 1$. Where the initial value of μ must be taken into account, this will depend upon the coil ampere-turns and magnetisation curve ; an average figure is 200.

Approximately 90 per cent. of the total heat is generated within a surface layer of this depth "p" around the cylinder. If we wish to heat the cylinder uniformly right through, we must heat at such a rate that, by heat conduction, the core temperature lags relatively little behind that of the surface. It can be shown that, for such cases, the frequency should be high enough to make "p" equal to or less than $\frac{1}{4} \times$ diameter of cylinder (3). If we wish to "surface harden" a steel cylinder, we must choose a frequency high enough to make "p" equal to or less than the hardened layer depth required (4).

In general, the clearance between coil and work-piece is made as small as conditions permit. In certain applications, *e.g.*, induction melting, the coupling between coil and charge is necessarily loose on account of the thickness of furnace lining required ; in a few cases, such as those in which a single-turn inductor fed from a "work-head transformer" can be used, a clearance of the order of $\frac{1}{16}$ in. may be permissible.

There is inevitably some power-loss in the coil itself, since it is not a perfect conductor. Also, the power-factor of the coil is low and lagging. Close coupling between coil and work reduces coil power loss (increases coil efficiency), and increases the power-factor.

Heating due to hysteresis loss in a magnetic work-piece is generally quite negligible in relation to the eddy-current heating ; the penetration of magnetic flux into the solid charge is of the same order as the nominal current penetration depth, and this is small even at 50 c.p.s. if the effective permeability is 200 or so. Consequently, although the hysteresis loss per unit volume of surface skin may be high, the total loss is relatively small.

High-frequency Power Sources.

Most applications of induction-heating require a frequency higher than that of the supply mains ; some form of frequency converter is therefore necessary.

Spark or arc oscillators, which produce a succession of damped trains of H.F. oscillations, played an important part in the development of induction heating, especially in small-scale melting. The noisy open rotary-spark-gap gave place to the quiet mercury-pool discharge chamber, and more recently the application of multiple quenched-spark gaps has increased the frequency range to 200-300 kc/s. (5).

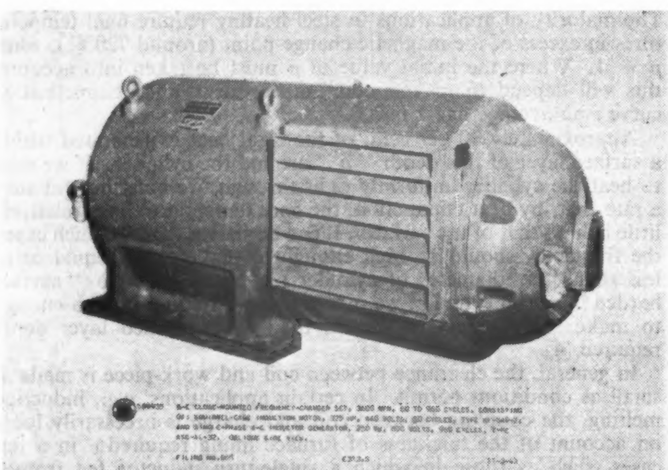

FIG. 2. Motor-generator, 250 kW output at 960 c.p.s.

The spark-gap H.F. generator is a simple static piece of equipment, relatively cheap in first cost. Its disadvantages are : Power rating limited to about 20 kW maximum H.F. output ; essentially a single-phase load on the mains, with a poor power-factor (0·5 to 0·6

lagging) ; need for very thorough screening to suppress radiation which, if allowed to occur, may affect telecommunication services seriously ; rather low power-conversion efficiency (40-50 per cent.).

The H.F. alternator was first applied to industrial induction-heating in the early nineteen-twenties. Since then the "salient-pole" wound-rotor construction has been largely superseded by the inductor alternator, which has no rotor windings. A recent improvement in design employs a system of stator notching which has resulted in a reduction in size and weight of an alternator, for a given rating, by comparison with conventional constructions (6).

The inductor alternator is now widely used for frequencies up to 10,000 c.p.s. ; the upper limit is at present about 50,000 c.p.s. Power rating up to 1,800 kW at 1,000 c.p.s., and 250 kW at 10,000 c.p.s. have been built. Melting, through heating of billets and bar-stock, and the heavier surface-hardening applications form the principal loads for these machines.

Small sets, up to 250 kW or so, are sometimes built as two-bearing machines, with motor and generator rotors on one shaft ; separate machines, directly coupled, are used for larger sets. The excitation of the alternator can be done from any convenient D.C. source, *e.g.*, a generator or a rectifier ; grid-controlled rectifiers, thyratrons, are employed in electronic voltage-regulator equipment having high-speed response.

The demand for power at frequencies from 100 kc/s or so up to at least several megacycles per second is now being met by that simple wonderful device, the high-vacuum thermionic triode valve. Used as a "class C" power oscillator, it converts D.C. power at several kilovolts to high frequency A.C. power with a conversion efficiency of 75 per cent. It is the most versatile of all the types of generators at present available, but its metier is unquestionably the surface hardening of components requiring a relatively thin case. Output power ratings from 5 to 100 kW are at present available.

Fourthly and lastly, mention must be made of the inverter, a new type of generator which may become widely used in a few years time. This relaxation oscillator employs grid-controlled mercury-vapour rectifiers, or alternatively ignitrons, and has a conversion efficiency of 90 per cent. or more. Unfortunately, the frequency limit is at present low (2,000 c.p.s. or so), and there are difficult technical problems to solve before it can be regarded as suitable for wide-scale use. The only publicised application of which we are aware is to the heating of large steel billets for forging (7).

Choice of Equipment (8).

In many cases the kind of H.F. plant to use is immediately obvious from power or frequency requirements ; in others any one of several kinds of plant could be used. For example, if a large amount

of metal is to be through-heated per hour, corresponding, say, to a H.F. power rating of 100 kW, and the work-pieces are bigger than ½ in. diameter, then the obvious choice would be motor equipment. Again, if steel spindles or shafts are to be surface hardened to a depth of ·020 in. or ·030 in., then valve-type generators would be used, because no other equipment is capable of generating a sufficiently high frequency (500 kc/s or so) for this shallow case to be realised.

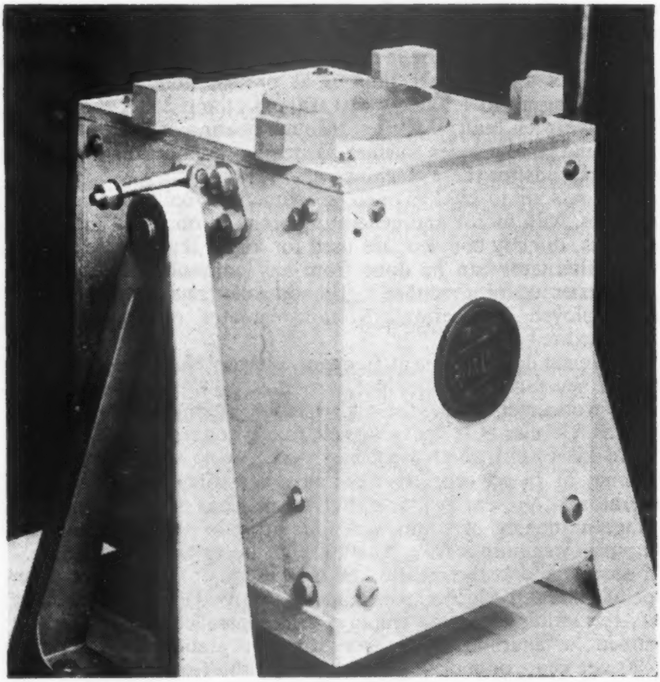

FIG. 3. Small high-frequency furnace for melting and casting special high-temperature alloys by the Durville method.

On the other hand, many localised-through-heating jobs, including annealing, hardening, brazing and stress-relieving, may be done equally well using spark, valve, or alternator sets. For supplying a single work-head, or a localised group of work-heads, the valve set is generally the most suitable in such cases, for power ratings up to 20 kW. Where it is required to have induction heating stations at

a number of points in a shop, then the alternator offers the great advantage of easy H.F. power distribution to the several points from a remote substation, using lead-covered or braided concentric cable. Although some such distribution is not impossible with valve oscillators, it is very much more difficult.

It should be noted that it is the normal practice to locate the necessary tuning condensers at the work-head in the case of alternator equipments, so that the distribution cables carry only the power-component, $\frac{1}{4}$ to $^1/_{10}$ of the furnace current. Although not essential, it is nevertheless usual to incorporate the tuning condensers in the oscillator unit in the case of valve and spark generators, and this means that the work coil must be not more than a few feet from the unit.

The extremely rapid heating and the automatic handling which are realisable with induction methods result in " furnaces " which are

FIG. 4. Semi-automatic local-hardening unit, with 5 kW 750 kc/s valve generator.

more akin to machine tool practice than to conventional heat-treatment, and such machines fit naturally into line flow production, the work-pieces being treated one by one, or in overlapping sequence, rather than in batches. Consequently, only a small floor space is required for such a furnace, and where shop space is at a premium the remote H.F. alternator substation is very attractive. The importance of taking full advantage of the possibilities of mechanisation and precise control inherent in the method cannot be over-emphasised. To ignore these possibilities is comparable to using a treadle lathe against a competitor's modern autos.

Line flow production methods are not, however, suitable for small quantity production, and although cases arise where induction heating is a legitimate method, and perhaps even the only possible method, of achieving a certain requirement, it is not usually applicable to a wide variety of small-quantity parts.

Applications.

We will now consider some of the many ways in which high frequency induction heating has been applied to industrial processes.

Melting (9). The earliest use of high frequency heating in industry was concerned with melting, and hundreds, if not thousands, of such units have been installed in all parts of the world. These furnaces range in size from units for melting a few ounces of gold or platinum, up to steel melting units capable of holding and melting 8 tons in three hours. For the small-sized melting units, such as are used in laboratories, and for the melting of small amounts of precious metals and other small production melts, the spark gap oscillator is used—and recently the valve type generator has been used for this purpose. The motor generator set is, by far, the most widely used for induction melting, firstly on account of its higher efficiency—secondly, because the stirring effect is more pronounced and, thirdly, the size of furnace is not so limited as in the case of the other type of generators.

The principal advantages of this type of furnace are :—

(1) Speed of melting—a 600 kW furnace will melt about 2,000 lb. of steel per hour.

(2) Stirring effect—this reduces time of alloying and de-oxidizing—also ensures more homogeneity of the alloying constituents.

(3) Lack of contamination of the metal by carbon due to the absence of electrodes.

(4) Improved operating conditions for the melter.

For the melting of ferrous metals, it is normal practice to use a non-conducting crucible or sintered lining, the energy for melting being induced directly in the charge. For metals having a high electrical conductivity, conducting crucibles made from clay and graphite are sometimes used.

Since this furnace finds its widest application in the melting of ferrous materials, any remarks on the operating efficiency of the high frequency melting unit will be confined to this industry.

FIG. 5. Work-head of unit shown in Fig. 4.

As a rough approximation, units ranging from 50 kW to 1,250 kW will melt from 250 lb. to 300 lb. of steel per hour for each 100 kW of generator capacity, but on account of the lower efficiencies of the small sized generators and furnaces, the overall consumption per ton will vary from 900 kilowatt-hours, in the case of a 50 kW unit, to about 600 in the case of the largest units. These consumptions correspond to overall efficiences of about 40 per cent. for the small units and 60 per cent. for the large furnaces.

The difference between the input of energy to the motor and that appearing as heat in the molten metal is made up of the losses in the motor-generator itself, the condensers and conductors, the I^2R loss

of the coil and the radiation and conduction losses from the crucible itself. These vary greatly according to size of generator and furnace, and the time of melting, and explain the wide variations in overall efficiency.

Surface Hardening (4). Of the more recent applications of induction heating, perhaps the most fascinating one deals with surface hardening. This is possibly the widest field of application, as it has numerous advantages over other methods of case hardening, such as carburising, cyaniding, nitriding, and flame hardening. The advantages of high frequency hardening may be summarised as follows—there is a minimum of distortion, as the heating is confined to the surface layers and the strength of the core is generally sufficient to prevent relative movement. The steels employed are normally low alloy or plain carbon, since depth of hardening is not necessary and water quenching is readily applied. There is no appreciable oxidation, as the time cycle is so short, quite frequently of the order of one or two seconds.

This means that a finished machined part can be hardened without the need for elaborate subsequent cleaning operations. As the hardening conditions can be predetermined and duplicated with great accuracy, absolute consistency can be guaranteed from part to part, and this can be attained with relatively unskilled operatives.

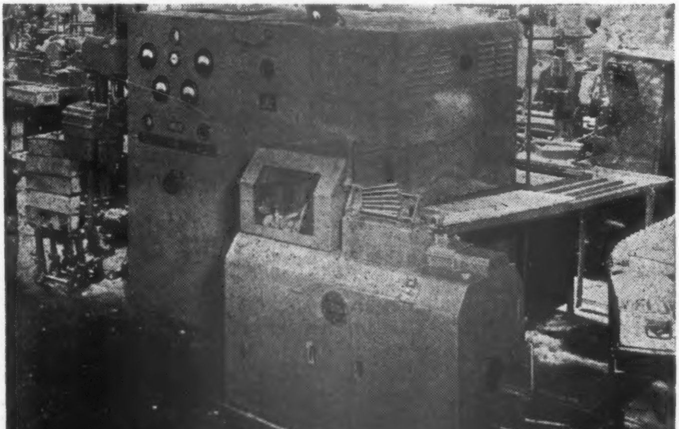

FIG. 6. Automatic unit for surface-hardening steel shafts. Output: 300 shafts per hour. Power supply: 20 kW 400 kc/s valve generator.

Moreover, the equipment is compact and occupies only a fraction of the floor space that is required for alternative furnace operations. The process is readily mechanised for most work and is conveniently adapted to line production. Among the other incidental advantages may be cited the absence of decarburisation, and the possibility of localising the hardening without the need for such cumbersome operations as copper plating or other methods of stopping off.

As regards economies of surface hardening, the costs will vary with different parts, but it should be said that, in general, they are only a fraction of carburising costs. The power consumption is extremely low, since only a very small amount of metal is heated. It is often found that about a ton of metal can be surface hardened for a consumption of some 100/200 kWh.

It should be remembered that it is primarily a mass production method. It would probably prove uneconomical to treat small quantities of many different parts, since it might be found that the time taken for changing inductors and quenching equipment would rule out this method of surface hardening.

Turning to the depth of case, it has been shown that frequency plays a large part. Equally important, however, is the rate of power input, since if this is too low the case effect will be destroyed on

FIG. 7. Magazine and discharge chute of unit shown in Fig. 6.

account of conduction of heat to the core. For large objects, the rate of heat conduction is of the order of 5 kW per square inch, when at the hardening temperature, so that the rate of power input must exceed this to produce an effective case. Generally, it is found that power inputs of from 8 to 15 kW per square inch are required, and the heating time is of the order of 1 to 4 seconds. If a part can be progressively hardened by passing it through a coil, as in the case of a shaft, then it is only necessary to heat a small portion of the surface at a time requiring, of course, a relatively small power input. Quenching is then done by means of a water spray.

As to methods of handling, these depend on the particular application. Shafts or rods, or even strip, can be fed progressively through a coil with a spray quench, and driven rollers can be used for transporting material. As there is practically no radiated heat, precision handling equipment can be employed, similar to that used in machine tool practice.

When it is considered that the material to be hardened is in the gamma range for only a fraction of a second, it is amazing that the carbides can go completely into solution in that time. The original condition of the steel is, therefore, of the utmost importance in this connection. The authors have seen an alloy steel in the spheroidized condition heated to 850°C. and quenched, and the material has not changed in hardness due to lack of solution of the carbides. The carbide size must, therefore, be fine, preferably in the sorbitic (hardened and tempered) condition, failing which a fine normalized structure is the next best. Since the heating time is so short, it is possible to exceed by 100 or even 200°C. the normal hardening temperature, to get more rapid solution of carbides, without producing any ill-effect on the steel. Care, however, must be taken not to produce retained austenite.

A wide range of parts is being satisfactorily treated by this method, of which typical examples are cam-shafts, crank-shafts, gears, spline-shafts, gudgeon pins, pump parts, sprockets, tractor pins, bearing surfaces, knife edges, and so on. The hardening of internal surfaces, although it presents more difficulties than the treatment of external surfaces, is being satisfactorily carried out with this type of equipment. Figs. 4 and 5 show a simple semi-automatic unit adaptable to a wide range of single-shot surface and local hardening of small parts. The power supply is from a valve oscillator with an output rating of 5 kW, and a nominal frequency of 800 kc/s. The work inductor, of the "concentrator" type, is housed in a brass box mounted above a steel cabinet which contains heat and quench timers and other auxiliary gear. The large top cover over the furnace is opened only for changing work-head transformers ; to load a work-piece, a small lid fitted in the top cover is opened. The lever on the right-hand side of the box raises

or lowers a stainless steel spindle, on which the work-piece is located. After heating, the work is quenched in position, the end of the heat-treatment cycle being indicated by a lamp.

An automatic equipment for surface-hardening ¾ in. diameter round and splined shafts is shown in Figs. 6 and 7. Only about 3½ in. length of the shaft is treated, the case depth being ·030 in. Driving motor, cam-shaft, oil pump and water filter are housed in the fabricated steel base ; the work-head transformer and the water spray-quench valve are located in a brass screening box above the mechanical gear. The magazine, to the right of this box, is loaded with shafts by hand. Each shaft in turn is taken automatically from the magazine, fed progressively through the "concentrator," and its integral quench spray, withdrawn again and discharged on to a roller conveyor. A 20 kW valve oscillator, nominal frequency 400 kc/s, provides the H.F. power, and the production rate is 300 shafts per hour. The shafts are finish-machined before this heat-treatment, and proceed therefrom to an assembly operation. This particular application of induction surface-hardening showed remarkable economies compared to the method previously used, the capital cost of the equipment being recovered within a few months of installation.

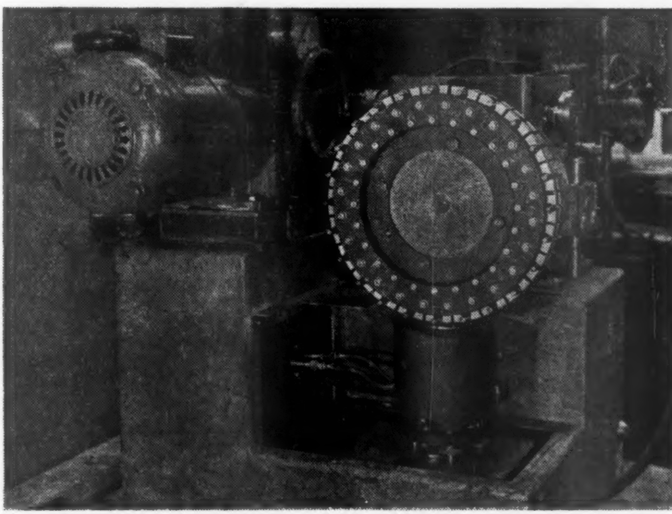

FIG. 8. Automatic handling mechanism for local hardening of small knife-edges. Guards removed to show work-head transformer.

Another progressive-surface-hardening machine is seen in Fig. 9. This loads a 45 kW valve oscillator, and treats $\frac{7}{8}$ in. diameter shafts up to 24 in. long for any selected part of their length up to the full

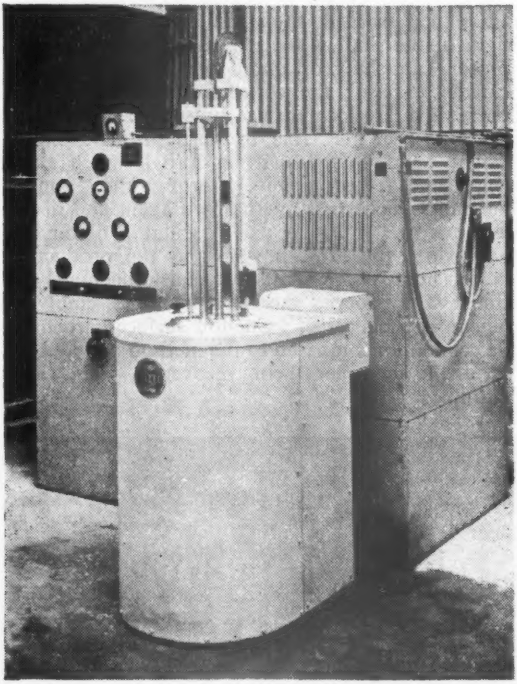

FIG. 9. Automatic machine for surface-hardening steel shafts up to 24 in. long.

length. The shaft, located vertically between centres, is fed downwards at a controlled speed through the inductor and quench spray ; H.F. power is then switched off and the shaft is returned quickly to the unloading position.

Through Heating.

Many different applications fall under this heading ; localized through-hardening of components, continuous progressive through-hardening and tempering of bar-stock, localized and entire heating of billets, bars, hollows, etc., for hot-working and so on.

The principal advantages accruing from the rapid heating and mechanized handling which are the essence of the induction method are:—

1. Scale formation greatly reduced, resulting in considerable saving in steel and, in hot-working, increased life of tools and elimination of "stickers."

2. Accurate automatic control of heating time and power, giving perfectly consistent results. Closer tolerance can be maintained, and often the rapid heating gives a much finer grain and a better product.

3. Greatly improved working conditions.

The time required to through-heat a section will depend upon the degree of uniformity desired between surface and centre temperatures; obviously the lower limit is set by incipient melting of the surface! There must be some temperature gradient from surface to centre while energy is being supplied to the steel, but this disappears within seconds of leaving the coil, in the case of billets up to several inches diameter. A good rule for through-heating time for round steel bars and billets is $25 \times d^2$ seconds, where "d" is the diameter in inches. Bars up to an inch or so

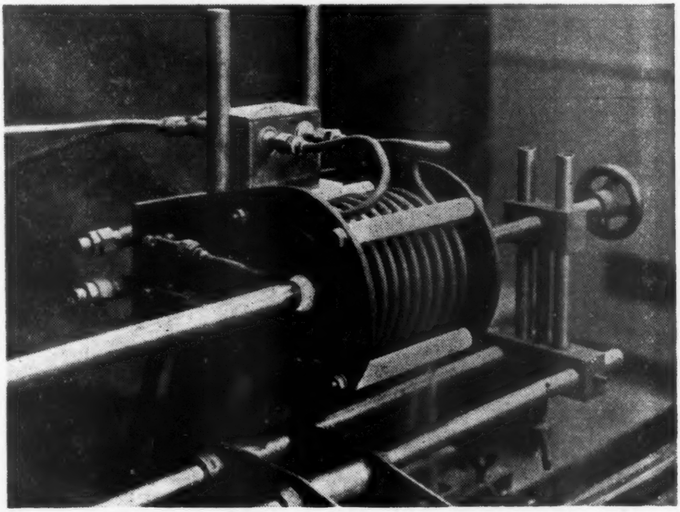

FIG. 10. Work-head transformer and experimental set-up for continuous progressive hardening of steel bars. The bar moves forward progressively through the single-turn inductor into a quench-spray.

diameter *can* be heated at speeds about twice this rate, but the maximum possible heating speed is not necessarily always the most suitable when all factors are considered. It will be noticed that, since both heat content and heating time are proportional to d^2, the upper limit of kW loading per inch length of billet will be approximately constant, independent of billet diameter. Using a constant of 25 in the expression for heating time, this loading is approximately 5 kW per inch, for steel bars and billets heated to 1,250°C. This is the coil H.F. power input required, per inch length of bar or billet, and includes coil loss and radiation loss.

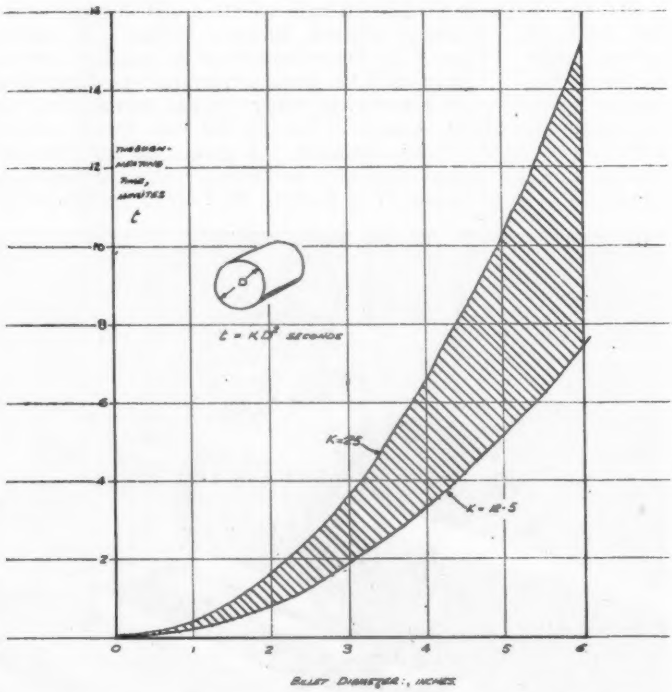

Fig. 11. Through-heating times for circular-section steel billets, for hot-working. Most applications fall within the shaded area bounded by the two curves, longer heating times corresponding to greater degrees of temperature uniformity through the section.

An application of localized through-heating for hot-working is seen in Fig. 12. This automatic machine has been developed for the bolt industry ; it discharges steel bars, heated at one end, to a heading press at any selected rate from 400 to 1,000 per hour. A magazine in the top is loaded with about half-an-hour's supply of ¾ in. or ⅞ in. diameter bars, which are then fed to six loading mechanisms associated with a 6-coil heater unit, are heated for a selected length (*e.g.* equal to 3 or 4 diameters), and then discharged down a chute at uniform intervals.

The six mechanisms operate in overlapping sequence, resulting in an almost steady load on the H.F. sub-station, the power ripple being $\pm$ 2 or 3 kW on a total load of 60 kW maximum.

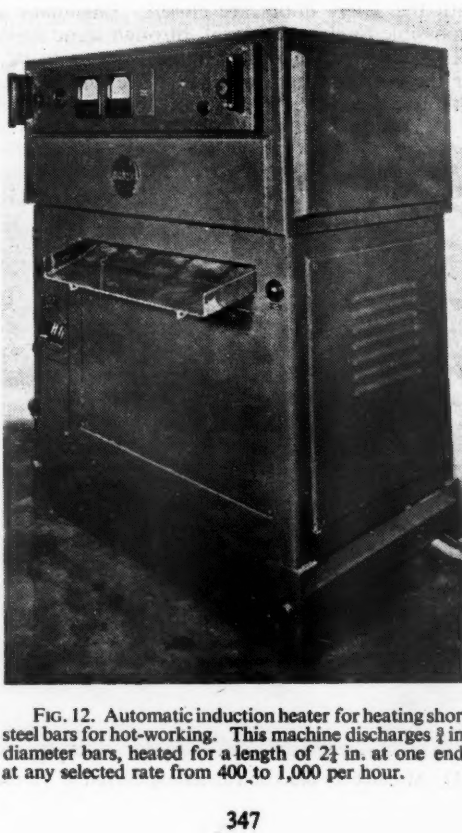

FIG. 12. Automatic induction heater for heating short steel bars for hot-working. This machine discharges ¾ in. diameter bars, heated for a length of 2¼ in. at one end, at any selected rate from 400 to 1,000 per hour.

Another interesting machine, for a somewhat similar application, is at present in the design stage. In this machine all the bars are loaded and unloaded automatically at the same fixed points. The output of heated bars will be 4,800 per hour, i.e., one every $\frac{3}{4}$ second, but because no magazine is required the overall size will be about the same as for the magazine-type described above.

A machine (for these furnaces *are* machine tools) for annealing the rim of a deep-drawn pressing, prior to a spinning operation, is illustrated in Fig. 13. There are two heating stations, and pressings are raised into the coils by means of compressed-air rams. Unloading and reloading are taking place at one station, while the other is heating, but both coils are continuously energized. The cycle time is determined by a motor-driven cam-shaft, but the rams will not operate until the safety doors are closed. Pneumatic door locks make it impossible to close a door if, through some delay, the door has not been closed early enough for the pressing to be held up in the coil for the correct length of time. The unit will anneal steel pressings at any desired rate from 150 to 450 per hour.

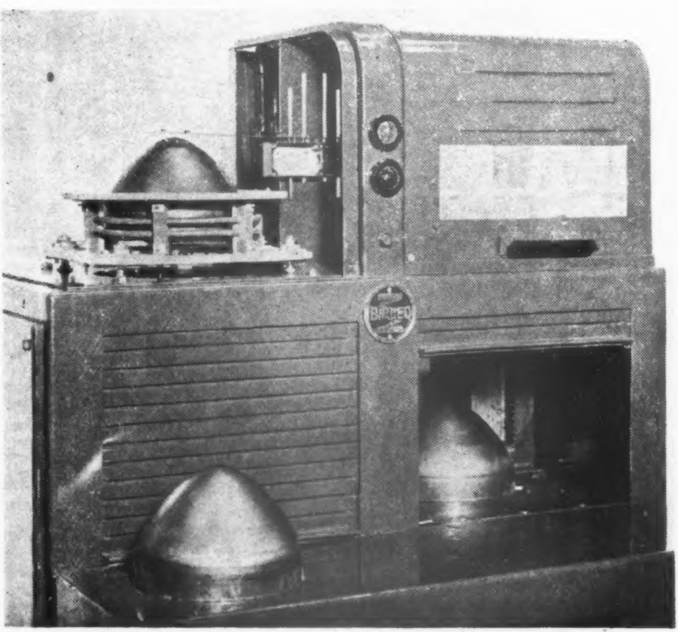

FIG. 13. Machine for induction annealing the rim of a pressing.

Brazing and Soldering.

A specialized application of rapid localized heating is that of brazing components by the use of copper, brass or silver solder. Providing the shape of the article is such that an inductor coil can be fitted round the joint to be brazed, it can show considerable advantages over other methods of brazing. Heating can be more rapid than with a torch and there need be no oxidation, as a reducing atmosphere can be used to shroud the work. As the heat is induced in the parts to be joined, thermal shock is less than with a torch, which is important in the case of brittle materials, such as carbide cutting tools. High frequency power is also often used for hard and soft soldering and an example of the latter is the high speed soldering of tin cans for small condensers, which is carried out on an endless belt made from non-conducting material.

Capital and Running Costs.

The heat units from high frequency energy may cost twice as much as those from mains frequency, yet it often happens that the actual energy costs for induction heating are much lower than for other

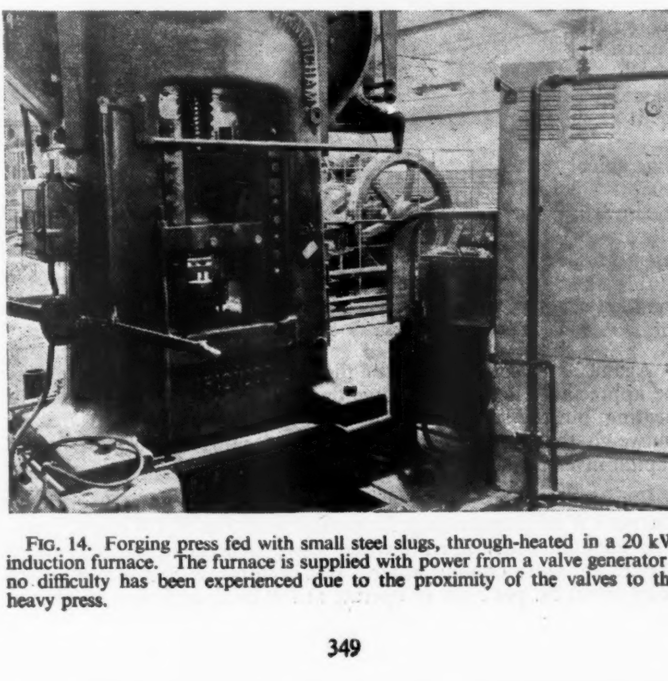

FIG. 14. Forging press fed with small steel slugs, through-heated in a 20 kW induction furnace. The furnace is supplied with power from a valve generator; no difficulty has been experienced due to the proximity of the valves to the heavy press.

methods because of the higher efficiency. In such cases, especially when one takes into account the other advantages associated with this type of heating, there is a clear case for induction.

FIG. 15. Experimental set-up for brazing operation on end-rings of small squirrel-cage rotor.

Again, as in certain types of through heating, energy costs may be appreciably higher for induction than an alternative method of heating, but the sum total of direct and indirect savings may easily outweigh the disadvantages of increased power costs and higher capital investment.

Generator Costs: Valve generators cost approximately £200 to £80 per kW of output rating, for ratings from 5 to 50 kW respectively. The running costs must include valve depreciation and, where applicable, valve cooling water. For example, a 20 kW output set costs about 5s. per hour to operate at full load, exclusive of labour.

Complete Motor Generator equipment for 10 kc/s costs from £100 to £25 per kW of output rating, for ratings from 25 to 500 kW respectively. This includes starter, isolator, voltage-regulator, output contactor, and series condenser. Running costs are lower per kW than for valve sets, actual mains energy input being the only significant item.

Energy Costs: The through-heating of steel bars and billets to 1,250°C. is effected, using motor-alternator equipment, with an expenditure of 1 unit of mains energy (*i.e.* 1 kW hr.) for about 5 lb. weight of steel heated. Surface-hardening costs can only be quoted for individual cases ; *e.g.*, the continuous surface hardening of ¾ in. diameter bars for their full length to a depth of ·030 in. corresponds to an expenditure of about 200 kW hrs. of mains energy per ton.

Steel melting costs have already been quoted as varying from 600 to 900 kW hrs. per ton.

Conclusions.

We have tried to cover, in a brief space, a wide range of applications of induction heating, that your interest in this new production method might be stimulated. There is often a tendency to try to apply a new method too widely ; on the other hand, there is sometimes reluctance to initiate a perfectly suitable application. Both extremes can be avoided by making available to production engineers information on the principles and practice of new methods as they develop.

The surface-hardening of regular sections, localized hardening and annealing, rapid through-heating for hot-working, through-hardening and tempering of bar stock, localized heating for brazing and soldering, and the melting of high-grade steels and alloys, are all legitimate applications for high frequency induction heating. Its widespread use in these fields is certain, especially where full advantage can be taken of the mechanization to which the method is so well suited. In many cases the combination of induction furnace and machine tool gives easier and better control of heat-treatment, and is therefore good engineering practice.

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As an emergency measure while the present paper shortage exists and to meet the demand of the continually increasing circulation, the advertisement section of this Journal is published in two editions, A and B. Advertisers' announcements only appear in one edition each month, advertisements in edition A alternating with those in edition B the following month. This Index gives the page number and edition in which the advertisements appear for the current month.

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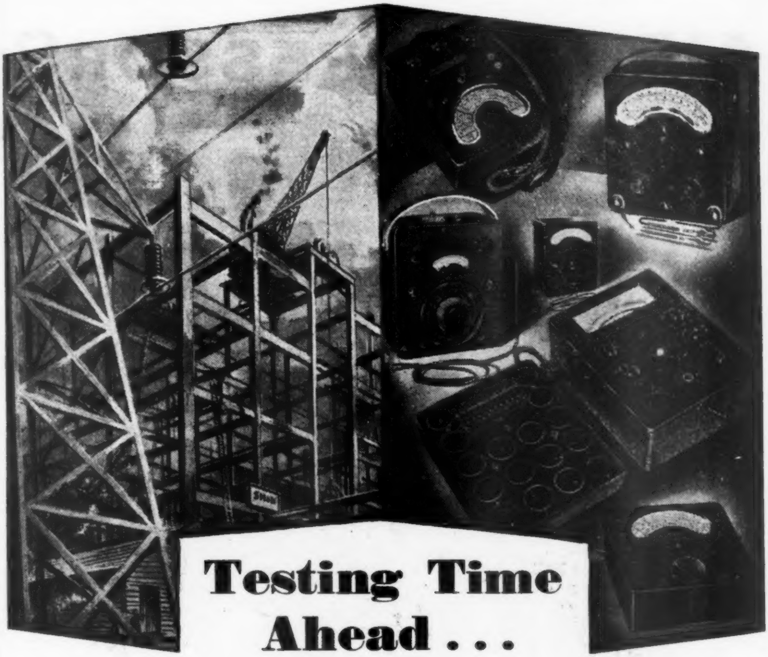


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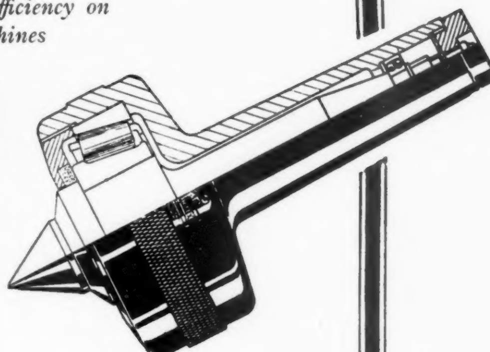

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Printed by Maxwell, Love & Co. Ltd., 10-15, Bradley's Buildings, White Lion Street, London, N.1.

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